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TOWARD A BETTER UNDERSTANDING OF THE ACQUISITION OF SKILL:  
THEORETICAL AND PRACTICAL CONTRIBUTIONS OF THE TASK APPROACH

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very fundamental research questions. It is argued here that this shift has not been particularly healthy for motor learning, because the tasks that were used have had questionable external validity, and the theories that were developed and evaluated were not maximally suited to the understanding of the phenomena of practice and learning. Two research programs noted deal with the effects of conditions of practice and feedback/knowledge of results, both of which offer a return to the task orientation.

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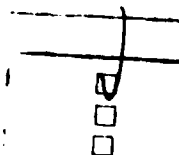
## SUMMARY OF:

### TOWARD A BETTER UNDERSTANDING OF THE ACQUISITION OF SKILL: THEORETICAL AND PRACTICAL CONTRIBUTIONS OF THE TASK APPROACH

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During the 1970s and 1980s, the field of motor learning generally abandoned the so-called task-oriented tradition, in which the effect of various experimental conditions on task performance or learning were evaluated. It was replaced by a process-oriented viewpoint, in which the dominant focus was the understanding of various underlying processes or mechanisms in performance and learning. Such a shift has resulted in many changes, such as a focus on relatively simple tasks where the underlying processes could be more easily identified, manipulated, and understood; and, it emphasized the concern for very fundamental research questions. I argue here that this shift has not been particularly healthy for motor learning, because the tasks that were used have had questionable external validity, and the theories that were developed and evaluated were not maximally suited to the understanding of the phenomena of practice and learning.

I have argued that a return to a task orientation will be important in carrying us forward in the next few decades. As support, I discuss two research programs which have used this tradition recently--one dealing with the effects of conditions of practice stemming from the work of Shea and Morgan (1979; Lee & Magill, 1983), and another dealing with feedback and knowledge of results emerging from Lavery's research (Lavery, 1962;



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Schmidt & Shapiro, 1985). In this work, the focus is on the conditions of practice which maximize learning of simple or complex motor tasks. The focus is solidly theoretical, and has already provided considerable theoretical thinking and empirical work examining the nature of these phenomena. But at the same time, these examples show much more external validity to real-world situations. Both ask about procedures that are actually used by people charged with the intelligent design of learning environments (the scheduling of practice and feedback). And, many of these examples could be easily conducted with more complex, realistic movement behaviors, with modern measurement capabilities being involved. Or they could even be conducted in practical settings themselves, perhaps in collaborative efforts with scientists in teacher behavior or movement education. As such, these two research situations provide interesting models for future efforts where theoretical and practical research goals can be achieved simultaneously. A return to the discarded task approach can provide many important contributions, and may even serve as the paradigm of the future in the motor learning area.

Understanding the acquisition of skill has been the focus of formal scientific interest for nearly a century, with a considerable increase in these activities in the 1960s. As beginning scientists at about this time, we were tremendously enthusiastic about the future of motor learning and its many relatives. Of course, for physical education one goal had always been the teaching of skills, and a vigorous approach to the scientific study of the motor learning seemed only natural. But more broadly, we were convinced that the acquisition of skill was a central concern for human functioning in general, being relevant to such diverse applications as job training and accident prevention in industry, artistic performance in music and dance, man-machine interactions in equipment and vehicle design, and the relearning of lost skill capabilities after traumatic injury or stroke. We believed that we could bring rigorous scientific procedures to bear on this largely under-studied area, and have a major impact both on theoretical understanding and on practical application. Now, some 20 years later, I find it interesting to consider what we have accomplished, what forces have acted to direct our thinking and research, and what we should do next in the study of these important general problems.

#### Motor Skills Acquisition--One View of Our Current Status

One of the major forces acting on researchers in motor behavior in the 1970s came from the idea, popularized by Pew (1970), that a so-called "task-oriented" approach to motor behavior was not going to be sufficient for the future. At about this time in psychology, there was a shift toward a

new cognitive tradition (Neisser, 1967), in which many underlying cognitive processes, stages, and mechanisms were being proposed and studied to account for observed behavior. This trend was paralleled by the call for process-oriented theories and research methods in movement behavior, in which analogous motor processes would be the focus of study rather than the overt movement behaviors of the earlier task-oriented tradition. This had a nice "ring" to it, as it seemed to allow researchers in movement behavior to develop and test theories concerned with the fundamental processes behind movement control and learning. And this style seemed to carry with it much more status—which was (unfortunately) quite important at the time—following as it did the current thinking in cognitive science.

### Process- and Task-Oriented Approaches

The paradigms associated with the older task-oriented approach tended to focus on the performance of usually rather global tasks such as the pursuit rotor, the Mashburn task, and the like, and asked about the effect of nearly countless variables that affected the nature of practice (e.g., massed vs. distributed practice, the nature of feedback, the effect of fatigue, etc.). These tasks were usually quite complex, involving many perceptual and motor processes simultaneously, and it was usually not possible to attribute performance changes to variations in a particular process (e.g., response programming). Also, while these tasks involved rather elaborate movement control, the measurement systems were usually quite gross, with a single score (time on target) summarizing perhaps 30 s of behavior.

Increased use of simple tasks. This new tradition demanded a change to



simpler tasks. We began to see many more studies using reaction-time to study the processes in motor programming, linear-positioning tasks to evaluate whether movements were based on displacement or distance cues, and ballistic-timing tasks to evaluate the role of error-detection processes. These tasks were well suited to the investigation of some questions, but were disappointing to those who wanted to understand how complex movement behaviors in everyday life were controlled and learned. The tasks involved performances that, for the most part, the learners could already perform (e.g., linear positioning); what was apparently learned in the laboratory was the "fine tuning" associated with making the particular already-learned action conform to the requirements of the experimental situation. Almost never were new coordinations learned, such as would be involved in learning a complex gymnastics stunt, and the movements were usually governed by a single degree of freedom. And, largely because of this, there seemed to be a systematic shift away from relevance to real-world motor behaviors. This shift is obvious when one examines the kinds of motor tasks that we were willing to label as "motor behavior."

Small amounts of practice. The study of learning gradually declined in popularity during this period, although there were exceptions. When learning was studied, it was usually done with these simple tasks, in which the improvements seemed to be extremely rapid; many learning experiments were done where the practice phase was a few dozen trials, and seldom did practice periods exceed 100 trials. The use of relatively small amounts of practice seemed to further remove us from relevance to real-world problems, as it was difficult to argue convincingly that the 50 trials or so of a linear positioning task were in some way informative about the

analogous processes leading to high-level skill in sport, industry, or music.

Simple tasks and motivation. These simple tasks had other problems as well. In our own research with various simple timing tasks, the learners tell us that the actions are overly simple. When lengthy practice is provided, the subjects often become quickly and visibly bored. With questionable subject motivation, we wonder whether we are meeting the basic assumptions for the meaningful study of learning. And, these difficulties meant that the problems of small levels of practice could not be met simply by increasing the amount of practice. What seems to be needed is more "interesting" tasks for the learners, which would sustain motivation through relatively advanced levels of practice, allowing the effects of various independent variables to be examined there.

#### Assumptions of the Process-Oriented View

But the criticism that the process-orientation led to tasks which were overly simple, and paradigms which were not particularly relevant to real-world behaviors, is perhaps too strong. Behind this research tradition are various assumptions which, if correct, would seem to argue that this approach will be most effective for understanding motor learning.

Principles of complex and simple tasks. One assumption is that the principles of movement learning will be the same for simple and complex motor tasks. That is, the effect of a particular independent variable (e.g., the nature of information feedback) will not interact with task complexity. If this assumption is correct, then it makes sense to study tasks which are simple, because measurement, control, and manipulation are far easier here

than in tasks which are more complex. But, if this assumption is incorrect, it is possible that the principles of learning derived from the study of simple tasks will be largely irrelevant to real-world situations involving more complex movement behaviors. We need solid evidence about the viability of this assumption, as seldom have the same variables been examined in the same way for simple and complex movements.

The levels of practice. A second assumption (also present in the task approach) is that the principles of learning will be similar for various levels of practice. That is, the effect of some independent variable will not interact with the level of practice of the learners. Thus, we are often tempted to talk about various "laws" of motor learning which are generated from tasks with very low levels of practice, thus assuming (or at least not seriously questioning) whether these principles will also apply for higher levels of practice so often seen in real-world situations. If this assumption is correct, much effort can be saved by examining simple tasks under relatively low levels of practice. But if, as many suspect, this assumption is not correct, then the low levels of practice that are typically used will have poor applicability to many real-world situations.

Technology has also played a role in these shifts, as response complexity usually implied measurement difficulties. Such problems were faced in the older task-oriented tradition by measurement of only the global response outcome (e.g., time-on-target for a 30-s trial), and ignoring the patterns of limb movement behavior completely. When the shift was made to the process-oriented approach, patterns of limb movement behavior were also ignored, but here by making the task so simple that the pattern of movement behavior was nearly trivial. Now, however, with the arrival of

affordable laboratory computer methods for the recording of various simple dimensions of limb movement (e.g., the position-time record of a hand-held lever), measurement problems in more complex behaviors can be examined in a time-efficient manner, and do not provide justification for avoiding complex movement behaviors in our research.

### Consequences of the Process Orientation

My own view is that, while this tradition has had a number of strong points and interesting findings, on the whole it has not been healthy. When I speak with my colleagues in other subfields of kinesiology, the sport sciences, or physical education, nearly all seem to agree that understanding the phenomena involved in the acquisition of skill is of central importance. But most politely hasten to add that our current field of motor learning does not address these questions very well. What, for example, can our field really tell, in some empirically based and non-intuitive way, about the teaching of Olympic athletes, the improvement of methodology in teaching, or the procedures used to train skilled workers in industry? Very little, I think (although there are a few bright spots which I will address in a later section). And, many university programs in physical education--even those focusing on the preparation of teachers--are increasingly discovering that they can do very well without courses in motor learning. Administrators apparently believe, with good justification, that coursework in motor learning is simply not relevant to the problems involved in teaching.

I want to be clear that I am not simply calling for an applied focus. Some (e.g., Adams, 1972; Schmidt, 1982) argue that an applied focus too

strongly emphasized can impede progress in a field because it prevents the establishment of more fundamental principles which lead to theory. The development of effective theory can, after some years of waiting for its refinement and testing, become enormously effective for guiding decisions about many practical matters. In this vein, Kerlinger (1973, p. 10) argued that "There is nothing more practical than a good theory." When these fundamental problems have been worked out, application to teaching situations (by us or someone else) should be relatively easy.

But the theories we developed and tested in the past decade or so have not been very satisfactory in meeting this objective. Many were too global (e.g., schema theory) to be an effective source of guidance for particular situations. These views have contributed to our overall insights about motor learning, but there is not enough that is concrete on which to base intelligent changes in practical circumstances. But perhaps more serious is the fact that most of these theories were studied with the simplistic tasks that seemed to be demanded by the process-oriented approach. Thus, even if the theories seemed to account relatively well for the data in such situations, the question is raised about the relevance of these tasks--and the theory that explains them--to any important real-world situation.

In many ways, this argument is parallel to that used by the ecological psychologists, who argue, for example, that the many investigations of "visual information processing" with tachistoscopic displays and suddenly presented stimuli were fine for telling us about these situations, but produced results and principles which may be largely irrelevant to understanding how an animal uses visual information to orient itself in the world (e.g., Turvey, 1977). In this sense, the process-oriented tradition for

motor behavior has led us to become extremely non-ecological in our research. We design tasks which are perhaps well suited for uncovering or manipulating a certain hypothetical process, but at the same time these activities may take us systematically farther from the understanding of "real" movement behaviors because they are so contrived, stripped of intrinsic feedback, or otherwise made artificial<sup>1</sup>. As Rosenbaum (1985) has said, the brain (and motor system, it must be added) can do many wonderful things; but it can also perform many silly things that we ask of it in the laboratory. One must wonder if the principles of learning the silly things discovered in the laboratory are going to tell us about "normal" movement behavior phenomena which motivated most of us in the first place.

Overall, my most critical view is that the field of motor learning has, with considerable success during the past decade or so, worked extremely vigorously and systematically--through the development of theoretical thinking, new experimental paradigms, and simple motor tasks--to become as esoteric and as irrelevant as it can be to the solutions of real-world problems. Part of the problem is based on status, where it became much more acceptable to study abstract problems of motor processes--with highly contrived and simple motor responses--than it was to examine problems which were more nearly representative of many real-world situations. Certain paradigms and tasks seemed to be used mainly because they were "in fashion." And, part of the problem has been a relative lack of interesting problems to examine with the procedures associated with the older task-oriented approach, with the newer issues about underlying motor processes apparently being genuinely more interesting to some.

This last point leads to the second major section of this paper. After a

decade or so of work associated with the process-oriented approach, a number of new ideas, methods, and empirical findings have surfaced which appear to provide justification for returning to the older task-oriented approach. And, these problems appear to have considerable potential for study in tasks with somewhat more complexity, and the principles that are emerging appear to be reasonably applicable to many real-world settings involving motor learning. Rather than, as one might assume, these benefits coming at the expense of theory development, many interesting theoretical ideas are being formed and tested in these situations, which should lead to a much better understanding of motor-learning processes in general.

#### Future Directions: Some Examples and Suggestions

The examples of these new directions for research in movement learning are numerous, but two major lines of work serve to illustrate this kind of direction very well. One of these directions involves some new thinking on various conditions of practice, and the other concerns the effects of various manipulations of feedback about goal achievement.

#### Research on the Conditions of Practice

Considerably after most of the field of motor behavior had either abandoned the study of learning, or had shifted to process-oriented studies of motor behavior, Shea and Morgan (1979) published a study which resides squarely in the task-oriented tradition. Their theoretical orientation stemmed from the late William Battig, who was interested in the idea that

various aspects of a practice situation which initially cause "difficulty" for the subjects (keeping slightly different versions of the tasks separate), and which make performance in practice poor, seem to provide greater learning of the task(s) when they are later evaluated on a retention test (e.g., Battig, 1966, 1979). This "intra-task interference," also called "contextual interference," had been studied to some extent in verbal tasks, but it had not really been generally recognized as an important factor for learning.

Shea and Morgan used a number of different versions of a relatively simple movement task, in which the learner had to begin with the hand on a "home" key, and then move to knock over three small barriers in a prescribed order before returning to the "home" position again; the task was to minimize movement time. Three different task versions involved placing the barriers in different positions, so that the movement directions and distances between them were different in the different tasks. Subjects practiced these three tasks in an acquisition session of 54 trials, where the order of practice was varied between groups. In one condition, practice was Blocked, in that 18 trials of Version A were completed, then 18 trials of Version B, and 18 trials of Version C. In the Random condition, the same number of trials of A, B, and C were completed, but the order was randomized, with no single version being present on two consecutive trials.

Figure 1 about here.

In Figure 1 (left) are the movement times for these two groups on the initial practice trials. The Blocked condition produced much more effective performance than the Random condition, with steeper improvements and faster movements at the end of practice. In Battig's terms, the mixing of the different versions of the tasks in the Random condition produced some



sort of contextual interference, making the performance of each of the versions of the tasks less effective than if the learners had an opportunity to work on each of the versions separately.

But the interesting finding occurs on the retention tests. The procedures generated essentially two separate experiments, where the effect of Blocked or Random practice in the acquisition phase was evaluated on (a) the Blocked retention tests or on (b) the Random retention tests, with retention tests either 10 min or 10 days after acquisition. These results are shown in the right portion of Figure 1. Consider first the Random retention tests, shown as the circles. Here the group with Random practice in acquisition (open circles) was far faster than the group with Blocked practice in acquisition (filled circles). Notice also that the Blocked-Random group performs better than the Random-Random condition in the acquisition phase, but that this order is reversed in the retention phase. It could be argued that the Blocked group in acquisition had to shift conditions to the Random retention test, whereas the Random group did not, and that this shift per se was in some way disrupting for the subjects.

However, this concern is reduced if we examine the Blocked retention tests, seen as the squares in Figure 1. Here, the Random-Blocked condition (filled squares) was faster than the Blocked-Blocked condition (open squares), and Random practice in acquisition was again more effective for long-term retention than Blocked, even though it was now the Random subjects who were required to shift conditions for the retention test. In general, subjects who practiced under Random conditions in the acquisition phase were more effective on the long-term retention tests, regardless of the conditions under which they were tested (Blocked or

Random), but the effect was much larger for subjects tested on the Random retention test.

These long-term retention tests, aside from providing evidence about the effectiveness of the conditions of practice in acquisition, have an important status of their own. In most real-world learning situations, we engage in practice to acquire the capability for responding that is to be demonstrated in the future. The dancer practices long hours during the week not so much because of effective performance in practice per se, but rather so that she can perform effectively in the concert next month. So this line of research on contextual interference tells us that, for maximization of the goal of effective long-term retention, excellent performance in the practice session per se is not necessarily the answer. It also suggests that we understand practice far less well than we are inclined to believe.

Theories of contextual interference. These effects, due in some way to the context in which a particular version of the task is practiced in acquisition, have been the subject of an interesting theoretical debate. Shea and Morgan (1979; Shea & Zimny, 1983) have argued that the effect is due to Random practice causing the subjects to process information about the various versions more "deeply" and completely, leading to increased distinctiveness between the tasks, more elaborate associations being formed for the various versions, and hence better long-term retention. Shea and Zimny, using post-practice interview techniques, found that the subjects reported many more descriptions of the tasks which used extra-experimental associations (statements similar to "That pattern looked like a Z") and intra-experimental distinctions ("This figure was like that one"), which tend to support their views about the deeper and more

elaborative processing as a basis for the better retention.

On the other hand, Lee and Magill (1983; Magill, 1983) have argued that the effects are caused by forgetting the solution to the movement problem--the way in which it was programmed or the particular strategy used, analogous to the views presented by Cuddy and Jacoby (1982). Here, the presentation of a different version (e.g., B) of the task causes the subject to forget the "solution" to the movement problem that was just generated on the previous trial (with Version A, for example), which then requires the learner to generate the solution for A again when it is next required. Subjects under Blocked conditions do not have to regenerate the solution on the next trial, because it is very similar to that just used on the previous trial. In this view, the generation of solutions to the movement problem is an important factor in learning, and conditions which prevent or minimize this generation process (e.g., Blocked practice) will be poor for learning and long-term retention as a result. These issues have generated considerable interest and attention, and a number of additional experiments.

Implications for future research directions. In addition to the interesting debate about the source(s) of these counterintuitive learning effects, implications for the problems raised in the first part of this paper are provided. First of all, the paradigms involve what most would classify as a task-oriented approach, in which the effects of some conditions of practice in the acquisition phase are evaluated on measures of learning (or retention). Second, such an approach is strongly theoretically motivated, with the conditions of practice being designed specifically to test various hypotheses about the nature of the learning effects (e.g., Lee & Magill, 1983). Thus, this style of work is not, as some have claimed about the

task-oriented approach in general, just empirically motivated, in which experimenters search without a theoretical direction for those conditions of practice which happen to be most effective for learning. The search identified here is a principled one, done for solid, fundamental reasons.

These aspects also contribute a great deal to other goals of motor learning research discussed earlier. For example, although Shea and Morgan's (1979) research uses relatively simple and artificial motor tasks, the tasks are, by almost any criterion, considerably more complex than those used in the process-oriented approach. And, even more complex tasks could have been used, with elaborate measures of the subjects' movement patterns perhaps being included. The result is that such work has considerably more relevance to many real-world situations.

But this feature has an additional, related aspect dealing with the applicability to teaching situations. The variable manipulated here--the nature of practice sequences--is one of critical importance for real-world teaching activities in physical education, music, and industry, where practice on various tasks has to be scheduled intelligently by instructors who wish to maximize learning efficiency. Not only can the findings that come from these laboratory experiments be reasonably safely generalized to real-world settings, they suggest experiments in naturalistic settings themselves. This latter aspect is particularly interesting for me, as I can imagine a new approach to the science of instruction (integrated with those concerned with teacher-learner interactions) based on paradigms of this general kind, and where the payoff is a theoretically oriented, empirically based, yet applicable study of practice phenomena. Viewed in these terms, the task-oriented approach appears to have much to contribute.

### Feedback and Knowledge of Results

A second general research area relevant to the present problem deals with what most workers in the field consider a critically important variable for learning--the information feedback received after attempting a movement. This feedback is usually called knowledge of results (KR), and is defined as verbal (or verbalizable) information, over and above that usually received in the task via other sensory channels, that evaluates the movement in terms of its environmental goal. Early work has shown that, if the task is structured so that the learners cannot obtain information about the consequences of the actions by themselves, then essentially no learning is achieved from practice unless KR is provided to inform about errors (Bilodeau, Bilodeau, & Schumsky, 1959; Trowbridge & Cason, 1932; see Salmoni, Schmidt, & Walter, 1984, for a review). Such findings have led researchers in the area to believe that KR is the single most important variable for learning, except possibly for practice itself (Bilodeau, 1966).

Methodological concerns with KR research. But our review of these issues (Salmoni et al., 1984) has led us to question some of these strong interpretations for KR and learning. Most of the studies examining the experimental manipulations of KR have conclusions based on the performances measured during the time that the KR variable is being manipulated. The difficulty is that one cannot be sure with this procedure whether (a) the experimental manipulation of KR has affected some relatively permanent acquired capability for responding (i.e., it has influenced learning), or (b) whether it has simply influenced performance

temporarily, in which case the beneficial effects of the KR manipulation would disappear when it is removed. There is ample reason to suspect that KR may have temporary performance effects, such as the well-known "energizing" (motivating) effects of KR, its guidance properties which tell the performer what to do next, and so on. The result is that what we thought were the principles of KR for learning may simply be principles of KR for temporary performance.

One solution to this problem is to examine performance on a retention test in which the KR has been removed. When this is done, the temporary effects of the KR manipulations are largely removed, leaving behind the relatively permanent effects which are the "products" of the learning process. A few, largely ignored, studies in the KR literature have used this procedure. When it is used, the effects of the KR manipulations (measured on the retention test) are often quite different from those seen in the acquisition phase. These results are often quite counterintuitive, suggesting major revisions about the principles of KR and learning.

Summary KR. Lavery (1962) examined a method of giving feedback termed "Summary KR," in which the experimenter drew a graph of the subject's performances over each of a series of trials, but the subject was only allowed to see this graph after 20 trials were completed. Other subjects received KR in the usual way (termed Immediate KR), while yet another group had both Immediate and Summary KR (Both). The performances of these three groups over 6 days of practice are shown in the left portion of Figure 2. The groups with immediate KR (Immediate and Both) were far more effective in performance than the Summary group, which performed relatively more poorly and improved at a slower rate.

Thus, because the Summary KR condition was very poor for performance, these and other findings have forced the view that Summary KR (and the so-called "trials delay" technique which resembles it) were devastating for learning (Bilodeau, 1956, 1966).

Figure 2 about here.

However, notice the performance differences when the KR is removed on a retention test (Days 7-10, 37, and 93). Here, the performance of the group with Summary KR in the acquisition phase is approximately the same as it was in acquisition, indicating very strong long-term retention; but the performances of the Immediate and Both conditions show large losses on Day 7, and continuing on subsequent days. If learning is measured, as I have suggested, via the performance on a no-KR retention test, then we are forced to the conclusion that Summary KR was the most effective practice method for learning. This is a very nonintuitive finding, because it suggests that the most effective conditions for performance during practice (Immediate and Both) are the least effective for learning. Furthermore, it was not the case that the Summary KR condition improved learning, because the Both condition also had the summary information, and it performed most like the Immediate condition in acquisition and retention phases. Rather, the conclusion seems to be that immediate KR in some was interferes with learning of the task, perhaps by causing the subject to be guided by it too heavily in the practice phase, as I suggested earlier (Schmidt, 1982).

Figure 3 about here.

Following Lavery's lead, my colleagues and I at UCLA have been investigating these and other similar phenomena. In one study, we (Schmidt & Shapiro, 1985) searched for an optimum number of trials for the summary

report. With a relatively simple timing task, we used summaries of 0 (i.e., immediate KR), 5, 10, and 15 trials, with these KR reports spread over 100 practice trials. Our results are shown in Figure 3, for immediate (10 min) and delayed (2 days) retention tests without KR. At 10 min, there was essentially no effect of the various feedback treatments manipulated in the acquisition phase. But by 2 days later, the errors were ordered inversely with the length of the summaries, with the 15-trial summary condition showing essentially no loss over 2 days, and the 0-trial summary condition showing considerable decrement. Again, this is a very curious finding, because the groups with the most effective performance during acquisition (here, the 0-trial summary condition) were the poorest in terms of learning, measured on a long-term retention test. All of these results suggest that we do not understand the processes of feedback utilization very well.

Implications for future research directions. These results on manipulations of KR, like those on context effects discussed in the previous section, share strong common implications for future of research directions. First, these findings are strongly empirically oriented, in that they are concerned with the fundamental relationships between the variations of KR and the subsequent learning and retention. The establishment of such empirical laws are absolutely essential for a field that claims to understand the processes in motor learning. But, these findings are also strongly theoretically oriented, in that they ask about how KR "works" to produce learning. Various theoretical ideas (such as the guidance hypothesis mentioned above) are possible to explain these effects, and considerable effort is being directed at understanding these phenomena. But what impresses me most about these results is their potential



applicability. These experiments manipulate variables (the schedule of delivery of information about response errors) which are under the direct control of teachers in real-world settings. It seems a relatively small jump from these laboratory manipulations to applications where summary KR procedures could be used. This kind of work seems to suggest studies actually conducted in natural settings, perhaps revealing instances where these variables would be most effective for maximizing learning, or uncovering limitations to generalizability. And finally, these results on KR utilization--like the context-effects research discussed above--represent an older task-oriented approach to motor learning, where various conditions of practice are manipulated to determine the effects on task learning. This suggests an important use for this old paradigm in the future.

### The Task Approach: Paradigm of the Future?

In asking about what kinds of empirical and theoretical directions we as a field of motor learning should take as we approach the end of this Century, I have tried to assess the contributions of the various approaches which have been predominant (at least in my brief tenure) in relation to the kind of problems that we are to address as a field. Many see our field (as I do) as the study of the acquisition of motor skills, with a major emphasis on the (empirical) principles of learning, on how these principles lead to theories about the underlying processes of learning, but at the same time with considerable focus on where these fundamental principles might be applied in real-world learning situations. If so, then the process-oriented approach so prevalent in the past decade does not suit my purposes very well, because

it has lacked two important features: (a) it seems to lack generality to real-world situations because of the emphasis on simple motor behaviors, and (b) it focuses on classes of fundamental problems which do not have obvious external validity. This situation is not necessarily related only to the task-orientation, but perhaps also to our underdeveloped thinking about fundamental principles of learning. But for whatever the reasons, I have argued here that, primarily because of the focus we have adopted during the 1970s, we have made ourselves largely irrelevant to the understanding of what most of us would agree are "interesting" motor skills.

I believe that one solution is to re-adopt the task oriented approach to the study of motor learning. In a discussion of these ideas with my long-time "colleague" and good friend George Stelmach, he asked essentially, "How can you really justify taking such a large step backward to a tradition we all rejected years ago?" My response, which is the theme of this paper, is based on a number of factors. First, if our field has to do with the establishment of empirical relationships between conditions of practice and learning, then it is clear that we have a long way to go before that goal is realized. Many interesting and important phenomena have never been studied seriously. And new findings, such as the KR and contextual-interference effects described here, suggest that we do not understand very much about the nature of such fundamental things as feedback and practice. The task approach is beautifully suited to the examination of such questions.

Second, the process approach has taken us away from situations which have much potential for practical application. Simple tasks and the focus on rather esoteric, overly simple theoretical ideas have not, in cold retrospect,

proven to be very useful either as explanations of motor learning, or as guidance for application. Perhaps it is too early to be so critical, as theories take considerable time to be developed and tested effectively. But the examples I have provided here suggest that use of the task orientation may be a more direct and effective way to understand problems relevant to our field. The problems here deal with effects of conditions of practice, an area of central interest to motor learning. The methods might (or might not) use more complex tasks which provide important increases in external validity. The ideas are strongly theoretical, and have led to many interesting explanations of practice phenomena and to experiments designed to test them.

Many of these problems could actually be conducted in real-world situations, sacrificing nothing with respect to experimental rigor (provided that the measurement system for the tasks is adequate), while gaining a great deal in terms of generality. Along these lines, I think it is time for an increased collaboration between motor learning and the new field known as "teacher behavior," whose primary concern is teacher-learner interactions in classroom situations, where often groups of learners with realistic tasks are involved. The new findings I have mentioned here, and numerous others, could form an attractive model for collaborative work between these two areas, as the findings have strong relevance to, and could be actually be replicated and extended in, classroom settings.

For some, my recommendation to "regress" to an earlier, and supposedly discarded, research tradition will seem strange and perhaps unworkable. But such an approach seems reasonable in light of my admittedly personal biases about the nature of the practical and theoretical goals of our field.

The research examples mentioned here, in which interesting theoretical and practical issues are studied simultaneously in the same experimental paradigm, represent excellent models for the nature of future work in this area, and seem to provide considerable justification for at least considering the task orientation as the paradigm of the future.

### Footnotes

1. But, to be fair, Zelaznik (1985) has pointed out that many of our real-world situations are pretty silly and non-ecological too, such as doing giant swings on the horizontal bar or flying a helicopter. It is just that these particular activities have, for various reasons, become popular and accepted as skills, where linear-positioning tasks and the like have not. And, perhaps because they are often nonecological and contrived, many accepted skills are "difficult" to perform, which makes them interesting as sports (pole vaulting), or important to study for societal reasons (e.g., helicopter safety).

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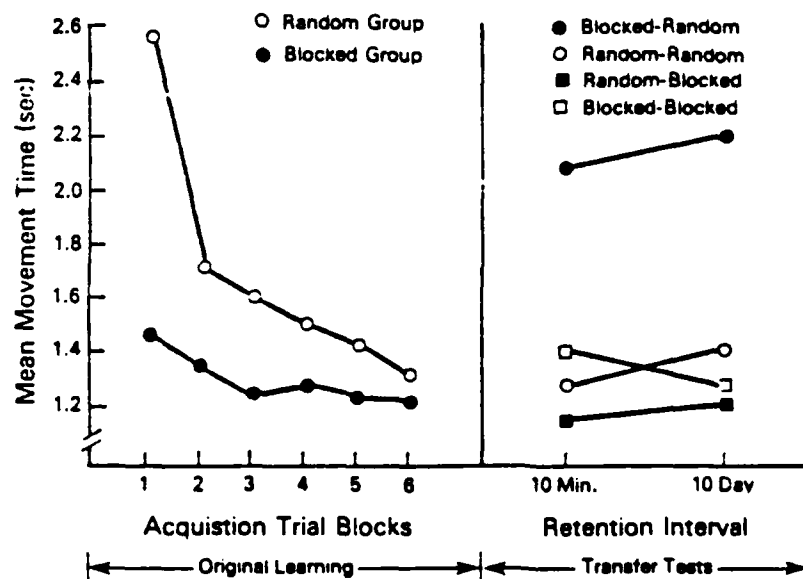


### Figure Captions

Figure 1. Mean movement time for a simple motor task acquisition and retention phases for Random and Blocked conditions of practice (from Shea & Morgan, 1979).

Figure 2. Mean percent correct responses in a simple movement task under three conditions of knowledge of results during an acquisition phase when KR is present, and during a retention phase where KR was withdrawn (from Lavery, 1962).

Figure 3. Mean absolute constant error for a simple timing task in immediate (10 min) and delayed (2 days) retention tests without KR as a function of the summary KR conditions in acquisition (from Schmidt & Shapiro, 1985).



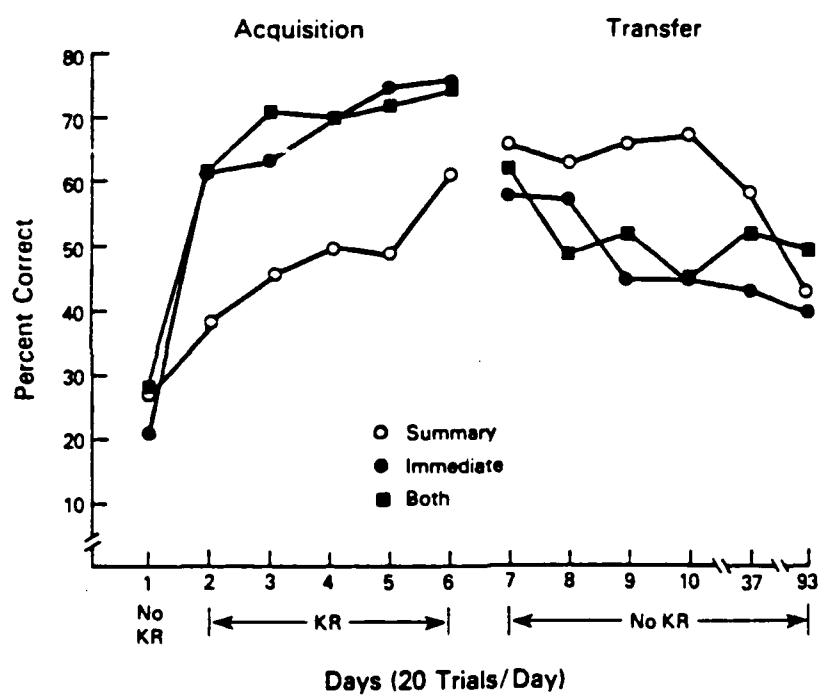


FIGURE 3

